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DC MICROGRID BASED SIMPLEX COMMUNICATION WITH CENTRALIZED WIRELESS FEEDBACK

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Abstract*— Power talk is a novel ultra-narrow band power line communication (UNB-PLC) technique for communication. Among the control units in Micro Grids (MGs). Unlike the existing UNB-PLC solutions, power talk does not require installation of additional dedicated communication hardware and, instead, uses only the power electronic converters through which the control units interface the common bus. This way the communication system has practically the same reliability as the power system. The information is transmitted by modulating the parameters of the primary control, incurring subtle power deviations that can be detected by other units. In this project, we develop power talk communication strategies for Direct-Current (DC) MG systems with arbitrary number of control units that carry out all-to-all communication. The proposed communication technique is challenged by the random changes of the bus parameters due to load variations. Simulations have been done with Matlab software using power system and communication tool boxes. To this end, we investigate the performance of power talk in a DC micro grid setup with DC loads connected in it. Faults are communicated to the central host using wireless link under 33MHz frequency signals. Simultaneously wired power line communication is done using DC bus available in the grid. A nominal level of encryption and channel coding has been done using microcontroller 89s52 at two ends and the communication system has a baud rate of 300 bits per second. The received data could be viewed in a separate LCD display. The effects of noise has been tried for the best to reduce it. The challenges in signal coupling in DC power line have been addressed

***Index Terms*— UNB-PLC, power talk, Direct-Current, encryption, LCD display.**

I. INTRODUCTION

Communications over power lines have a history of more than a hundred years. The first applications required only very low bit rates, as they included control signaling, metering and load management. The rapid development of communications' technology recently made it possible to use the power line network for high speed transfer of data. Moreover, as access to Internet is becoming as indispensable as access to electrical power and the need for in-home local area networks is increasing continuously, power line communications(PLC) offer a potentially convenient and inexpensive solution. The unique fact that no new wires are needed, the availability of power outlets in every room and the easiness of installation give PLC the opportunity to compete with other "last mile" technologies, such as digital subscriber line (DSL), wireless local loop, wireless LANs and telephone lines. PLC access networks cover both the public area from the transformer substations to the customer premises (outdoor) and the private area within the customer buildings (indoor). Most of the systems available provide a maximum data rate of more than several Mbps. However, power line grid can be characterized as a rather hostile medium for data transmission, because it was originally designed for the distribution of electrical power in the frequency of 50-60Hz. As a consequence, PLC channel faces some technical problems, such as impedance variations and mismatches, various forms of noise and narrowband interference, multipath propagation phenomena and high attenuation of the medium. Further research should be carried out in the fields of efficient coding, modulation and transmission methodologies, in order to ensure reliable communication over power lines. Space-Time coding is a new coding modulation technique for multiple antenna wireless systems. Multiplexing is an essential part in a communication system where multiple data streams are transmitted simultaneously through a single link. Multimedia data streams such as video, audio and high quality digital images have special requirements that are hard to be met, especially by power line communication systems (PLC). High bandwidth, small transmission delays and channel reliability are required for on-time data stream delivery and real time playback [1]. However, the nature of the transmission medium in PLC degrades significantly the performance, since attenuation and noise levels are often excessive [2, 3]. The proposed paper evaluates the performance of multimedia transmission in impulsive noise environments and presents methods to improve the Quality of Service (QoS).

Additionally, an advanced multiplexing strategy combined with a forward error correction code is demonstrated and simulation results are provided. The increasing demand for data and voice transmission over the past years, has led to a "spectrum drought," implying that alternative ways of communication are fundamental. Power-line communications (PLC) constitutes an innovative manner of information exchange. They imply transmission of the telecommunication signal through the public power network, which makes this new technology appealing since the existing infrastructure is utilized and there is no need for wires. On the other hand, there are several drawbacks concerning this technology, which need to be overcome for better system performance. One main drawback is that the network was not originally designed for high-frequency signals; therefore, it introduces great variance to different signal components. Furthermore, due to the changing load on the power network, impulsive noise is added to the communication signal, which makes it even harder for the data to be recovered at the receiver. In order to simulate a PLC system, it is essential that the channel characteristics are modelled. In the literature, there are several channel models available. One of the first channel models was introduced by Hensen and Schulz, which was a simple model implying that the attenuation increased with frequency [1]. “Philipps” model was introduced next, and tookinto consideration the multipath effect of the transmission through the power lines’ network [2]. This model is applied in the time domain, since it entails each path’s delay in time. A frequency-domain channel model was introduced by Zimmermann and Dostert, [3]. This model not only estimates the delay that each path encloses, but also the attenuation that it undergoes due to the wire’s length. Therefore, it is considered to be a more in-depth channel model. Moreover, Banwell andGalli proposed a channel model based on the multiconduct or transmission-line theory, where, the power line can be represented by an equivalent circuit [4], [5]. Finally, there are several channel models introduced by various researchers which are based on measurements [6]–[8]. In this paper, Zimmermann’s model is used, because it is easy to apply. It takes many parameters into account and is used a lot in the literature as a reference channel model.

It should be also mentioned that the telecommunication signal suffers deterioration due to the noise added by the channel. The noise can be divided into two categories: 1) background noise and 2) impulsive noise. Similar to the occasion of channel models, there are several noise models available in the literature for background and impulsive noise. The majority of these models are based on measurements. Some examples of such models can be found in [9]–[15]. One popular noise modelused by a lot of researchers in the literature is Middleton’s model [16], which we also take into account in our study. According to this model, the total noise consists of two parts, describing the background and impulsive noise, respectively. However, according to [15], it does not describe impulsive noise in the most accurate way. Therefore, we introduce a new way of estimating the impulsive noise by exploiting the noise bursts’ properties. According to these properties, noise bursts are Poisson distributed with an impulse arrival rate of

$$0 \leq \lambda \leq 5 * 10^{(-3)}$$

whereas their duration takes no longer than 0.1 ms [9]. Keeping these properties in mind, the impulse noise’s effect on our data can be easily derived, as explained further in the next section. In order for a complete PLC system to be simulated, coding and modulation techniques should be implemented. In this paper, we introduce array codes and specifically generalized array codes (GACs) and row and column array codes (RACs) as the system’s coding scheme. These codes are mainly examined by Soyjaudah, [17]–[19] and Feng [20], [21]. However, never before have they been used in a PLC environment. Thus, it is practical to study their effectiveness in a PLC channel.

II. POWER LINE COMMUNICATION

Power line communication or power line carrier (PLC), also known as power line digital subscriber line (PDSL), mains communication, power line telecom (PLT), power line networking (PLN), or broadband over power lines (BPL) are systems for carrying data on a conductor also used for electric power transmission. A wide range of power line communication technologies are needed for different applications, ranging from home automation to Internet access. Electrical power is transmitted over long distances using high voltage transmission lines, distributed over medium voltages, and used inside buildings at lower voltages. Most PLC technologies limit themselves to one set of wires (such as premises wiring within a single building), but some can cross between two levels (for example, both the distribution network and premises wiring). Typically transformers prevent propagating the signal, which requires multiple technologies to form very large networks. Various data rates and frequencies are used in different situations. A number of difficult technical problems are common between wireless and power line communication, notably those of spread spectrum radio signals operating in a crowded environment. Potential interference, for example, has been a long concern of amateur radio groups.

A. *Basics*

Power line communications systems operate by impressing a modulated carrier signal on the wiring system. Different types of power line communications use different frequency bands, depending on the signal transmission characteristics of the power wiring used. Since the power distribution system was originally intended for transmission of AC power at typical frequencies of 50 or 60 Hz, power wire circuits have only a limited ability to carry higher frequencies. The propagation problem is a limiting factor for each type of power line communications. Data rates and distance limits vary widely over many power line communication standards. Low-frequency (about 100-200 kHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second; however, these circuits may be many miles long. Higher data rates generally imply shorter ranges; a local area network operating at millions of bits per second may only cover one floor of an office building, but eliminates the need for installation of dedicated network cabling.

Different communication technologies are being used for the transmission of information from one end to another depending on the feasibility and needs. Some include Ethernet cables, fiber optics, wireless transmission, satellite transmission, etc. A vast amount of information travels through the entire earth every day and it creates an essential need for a transmission medium that is not only fast but economically reasonable as well. One of the technologies that fit in the above stated criteria is **PLCC**.

PLCC, **Power Line Carrier Communication**, is an approach to utilize the existing power lines for the transmission of information. In today’s world every house and building has properly installed electricity lines. By using the existing AC power lines as a medium to transfer the information, it becomes easy to connect the houses with a high speed network access point without installing new wirings. This technology has been in wide use since 1950 and was mainly used by the grid stations to transmit information at high speed. Now a days this technology is finding wide use in building/home automation as it avoids the need of extra wiring. The data collected from different sensors is transmitted on these power lines thereby also reducing the maintenance cost of the additional wiring. In some countries this technology is also used to provide Internet connection. The idea of using an existing medium to send the communication signals is as old as the telegraph itself. But it had not been possible until the recent decades. The first significant step in the field was when two patents were issued to American Telephone and Telegraph Company in the name of 'Carrier Transmission over Power Circuits' in 1920. After four years later in 1924 two other patents were filed for the systems transmitting and receiving communication signals over three phase power lines. Harsh characteristics of the power cables were the key problem in further development. Researchers were involved to overcome the unpredictable characteristics of the power lines. Since the early 1980, spread spectrum power line communication was the main focus of the research. This technology is now developed far better than that initial improvement and is promising a reliable utilization in home automation and security systems.

B. Applications of PLCC

PLCC technology can be deployed into different types of applications in order to provide economic networking solutions. Hence merging with other technologies it proves useful in different areas. These are few key areas where PLC communications are utilized:

i. Transmission & Distribution Network:

PLCC was first adopted in the electrical transmission and distribution system to transmit information at a fast rate.

ii. Home control and Automation:

PLCC technology is used in home control and automation. This technology can reduce the resources as well as efforts for activities like power management, energy conservation, etc.

iii. Entertainment:

PLCC is used to distribute the multimedia content throughout the home.

iv. Telecommunication:

Data transmission for different types of communications like telephonic communication, audio, video communication can be made with the use of PLCC technology.

v. Security Systems:

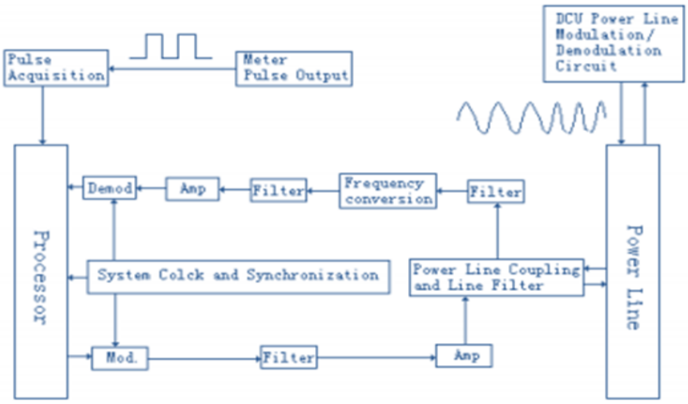
In monitoring houses or businesses through surveillance cameras, PLCC technology is far useful.

vi. Automatic Meter Reading

Automatic Meter reading applications use the PLCC technology to send the data from home meters to Host Central Station.

C. Operating Principle

The communication device used for the communication over the power lines is a MODEM, commonly known as **Power Line MODEM** (PLM). It works as both transmitter and receiver, i.e., it transmits and receives data over the power lines. A power line modem not only modulates the data to transmit it over the power lines and but also demodulates the data it receives from the power lines. By using modulation techniques, binary data stream is keyed on to a carrier signal and then coupled on to the power lines by PLM. At the receiver end another PLM detects the signal and extracts the corresponding bit stream.



Signal, Data and Information Flow:

The above image shows the working of a PLCC system. Data is processed before transmission on power lines according to the above figure. First data is modulated & filtered and then by using couplers, it is sent over the power lines.

D. PLC Modems/Transceivers

PLC Transceiver is the key component of a PLCC system. It is the device which transmits & receives data to & from the power lines and acts as a hub between the power stations and our Computers/Network utilization devices. They are wired with the electrical voltage lines at home or business and work on two modes – transmit mode and receive mode. In transmit mode, they simply receive data from receiver end installed on the same network and further transmit them. In receive mode, they work the opposite way.A number of companies provide PLC transceivers and other networking devices for PLCC communication. A PLC transceiver is shown in the following image.

E. Modulation Techniques

As mentioned earlier, characteristics of the power line channel continuously vary with time and load. So conventional modulation techniques like ASK, FSK or PSK cannot be employed with them. PLCC needs a technique that can deal with the unpredictable attenuation and phase shifts. Modulation techniques that opt lower frequency ranges of 35 KHz to 95 KHz can perform better as compared to the ones using the whole available frequency band. OFDM (**Orthogonal Frequency Division Multiplexing**) is the modulation technique that is used in Home Plug specification network appliances. In OFDM, **information is modulated on to multiple carriers**, where each carrier occupies its own frequency in the range of 4.3 to 20.9 MHz. Incoming bit stream is demultiplexed into N number of parallel bit streams each with 1/N of original bit rate which are then modulated on N orthogonal carriers. By using multiple carriers at a time, the modulation technique uses the available spectrum most efficiently. During the transmission, each frequency is monitored and if any interference, noise or data loss occurs, the responsible frequency is removed. However this technique does not perform well when a large attenuation and jamming occurs in the communication channel, but still it can be very efficient comparatively.

i. Signal to Noise Ratio:

Signal to Noise Ratio (SNR) is a measurement of quality of the signal. It indicates the amount of the noise in a signal. SNR can be formulated in the following way:

SNR = Received Power / Noise Power

Increasing SNR means increasing the performance of the communication system. By applying noise filters on household appliances, the noise entering into the power system can be reduced. However it will increase the cost of the appliances but is a better solution to improve overall performance.

ii. Signal Attenuation

Signal attenuation is basically the reduction in strength of the signal. A signal attenuation of about 100dB/Km occurs for low voltage power lines and 10dB/km for high voltage lines. It creates a need of continuous repeaters over a fixed distance. A number of factors that are responsible for signal attenuation include distance, time, frequency of the signal, etc.

iii. Failure scenarios

There are many ways in which the communication signal may have error introduced into it. Interference, cross chatter, some active devices, and some passive devices all introduce noise or attenuation into the signal. When error becomes significant the devices controlled by the unreliable signal may fail, become inoperative, or operate in an undesirable fashion.

1. **Interference:** Interference from nearby systems can cause signal degradation as the modem may not be able to determine a specific frequency among many signals in the same bandwidth.

2. **Signal Attenuation by Active Devices**: Devices such as relays, transistors, and rectifiers create noise in their respective systems, increasing the likelihood of signal degradation. Arc-fault circuit interrupter (AFCI) devices, required by some recent electrical codes for living spaces, may also attenuate the signals.

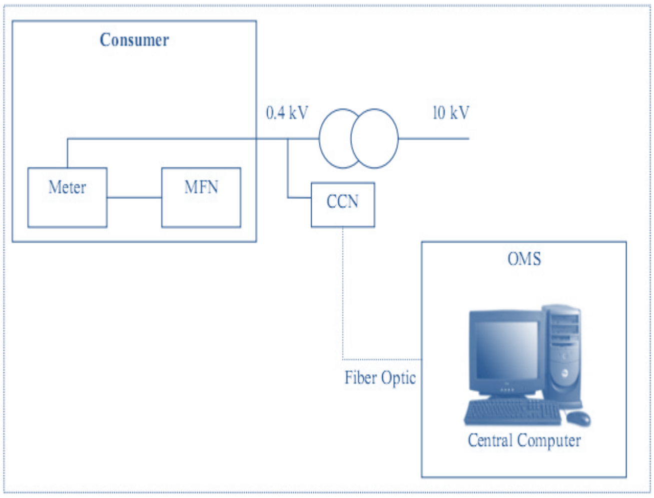
3. **Signal Attenuation by Passive Devices**: Transformers and DC-DC converters attenuate the input frequency signal almost completely. "Bypass" devices become necessary for the signal to be passed on to the receiving node. A bypass device may consist of three stages, a filter in series with a protection stage and coupler, placed in parallel with the passive device.

F. Standards

Two distinctly different sets of standards apply to power line networking as of early 2010. Within homes, the Home Plug AV and IEEE 1901 standards specify how, globally, existing AC wires should be employed for data purposes. The IEEE 1901 includes HomePlug AV as a baseline technology, so any IEEE 1901 products are fully interoperable with HomePlug AV, HomePlug Green PHY or the forthcoming HomePlug AV2 specification (under development now and expected to be approved in Q1 2011).

i. How PLCC technology is used in meter reading?

Automatic Meter Reading using PLCC technology is quite useful as it saves a lot of human efforts and also makes the whole system more efficient. The automatic meter reading system consists of three components, namely, Multifunction Node (**MFN**), Concentrator & Communication Node (**CCN**) and Operation & Management System (**OMS**). Different components and their inter-connections are shown in the figure.



MFN is a unit installed in household meters, either incorporated in the meter itself or externally connected to it.

Its function is to take reading of the meter on an hourly basis and store it in a memory chip. CNN is another part which manages all MFNs within a particular area and collects meter readings from all MFNs. It is generally installed on substations and needs a computer. The computer is installed with Operation and Management System (OMS) which further manages all the data and meter readings from CNNs.

PLCC Standards

Proper standardization makes a technology comprehensive and deployable. A few standards pertaining to PLCC exist in different parts of the world.

1. European Committee for Electrotechnical Standardization (CENELEC)

Countries from the Western Europe formed a standard known as CENELEC standard to standardize the issues and concerns related to power line communication. This standard defines standards for allowed frequency ranges and output voltages for the communication over power lines.

A frequency range of 3 to 148.5 KHz is allowed for the communication and this range is further divided in 5 sub-bands. These are according to the following table:

Band	Frequency Range	Usage
	3KHz – 9KHz	This range is restricted to the Energy Providers.
A-Band	9KHz-95KHz	Restricted to the energy providers and their concession holders
B-Band	95KHz-125KHz	Restricted to the energy providers customers. There is no access rule defined for this frequency range.
C-Band	125KHz-140KHz	Restricted to energy providers customers. Simultaneous operations on multiple systems are possible for this frequency band, A protocol named Carrier Sense Multiple Access Protocol is defined for this using a frequency of 132.5KHz.
D-Band	140KHz-148.5KHz	Restricted to customers. No access protocol is defined for this band.

2. Federal Communications Commission (FCC)

FCC standardizes the frequency ranges and transmitted power ranges for the power line communications in North America. The allowed base frequencies range from 0 to 530 KHz.

3. HomePlug Powerline Alliance

HomePlug Powerline Alliance is a group of companies dedicated to improve the technology for the networking and communication over power lines. In June 2001, first specification named HomePlug 1.0 was launched.

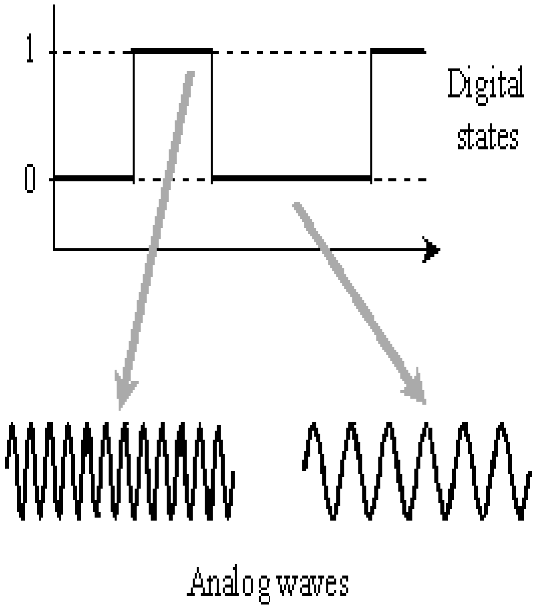
The standard uses a physical layer protocol (PHY) based on 128 equally divided carrier OFDMs (Orthogonal Frequency Division Multiplexing) from a frequency range of 0 to 25MHz. It uses concatenated Viterbi and Reed Solomon coding for payload data, Turbo product codes for control data and BPSK, DBPSK, DQPSK or ROBO modulation with a cyclic prefix for modulation of the data.

4. IEEE 1901

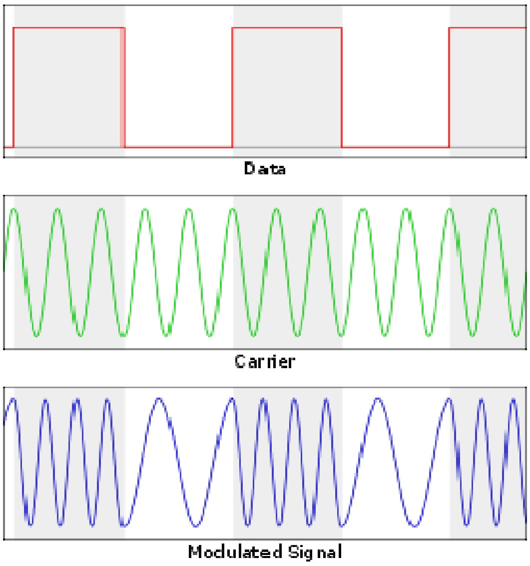
Institute of Electrical and Electronics Engineers (IEEE) stated a standard named IEEE 1901 for high speed power line communications. This group was formed in 2005 and gave its first standard in 2010 which includes two different physical layers, first one based on OFDM modulation and the other one based on wavelet modulation. Network devices that employ only OFDM physical layer will not be interoperable with the device that employ Wavelet physical layer.

III. FREQUENCY-SHIFT KEYING (FSK)

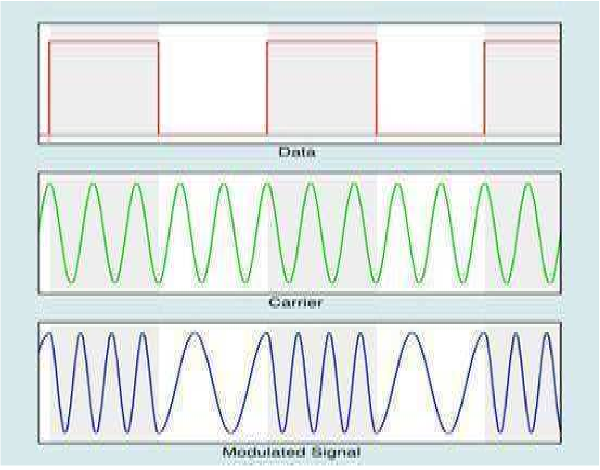
Frequency-shift keying (FSK) is a method of transmitting digital signals. The two binary states, logic 0 (low) and 1 (high), are each represented by an analog waveform. Logic 0 is represented by a wave at a specific frequency, and logic 1 is represented by a wave at a different frequency. A modem converts the binary data from a computer to FSK for transmission over telephone lines, cables, optical fiber, or wireless media. The modem also converts incoming FSK signals to digital low and high states, which the computer can "understand."



The FSK mode was introduced for use with mechanical teleprinters in the mid-1900s. The standard speed of those machines was 45 baud, equivalent to about 45 bits per second. When personal computers became common and networks came into being, this signaling speed was tedious. Transmission of large text documents and programs took hours; image transfer was unknown. During the 1970s, engineers began to develop modems that ran at faster speeds, and the quest for ever-greater bandwidth has continued ever since. Today, a standard telephone modem operates at thousands of bits per second. Cable and wireless modems work at more than 1,000,000 bps (one megabit per second or 1 Mbps), and optical fiber modems function at many Mbps. But the basic principle of FSK has not changed in more than half a century.



Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is *binary FSK* (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency. The time domain of an FSK modulated carrier is illustrated in the figures to the right. In Frequency Shift Keying, the modulating signals shift the output frequency between predetermined levels. Technically FSK has two classifications, the non-coherent and coherent FSK. In non-coherent FSK, the instantaneous frequency is shifted between two discrete values named mark and space frequency, respectively. On the other hand, in coherent Frequency Shift Keying or binary FSK, there is no phase discontinuity in the output signal.



In this digital era, the modulation of signals are carried out by a computer, which converts the binary data to FSK signals for transmission, and in turn receives the incoming FSK signals and converts it to corresponding digital low and high, the language the computer understands best. There are Frequency Shift Keying standards, used in various countries across the globe. They are the ETSI FSK, Bellcore FSK, BT (British Telecom) FSK and CCA (Cable Communication Association) FSK. The Bellcore standard is used in United States, Australia, China, Hong Kong and Singapore. It uses the 1200 baud Bell 202 tone modulation and the first bit of data is transferred after receiving the first ring tone. The BT FSK or British Telecom Frequency Shift Keying is an original standard that was developed by the British Telecom. This standard wakes up the display with a line reversal and transmits the data as CITT V23 modem tones, a format similar to MDMF. British Telecom itself uses this standard as well as some wireless networks such as the late Lonica and some cable companies as well. More details about the British Telecom Frequency Shift Keying standards can be obtained from the document Designing Caller Identification Delivery Using XR-2211 for B.T. or the Supplier Information Notes (SINs) 227 and 242.

In Cable Communication Association standard, data is sent after a short first ring, either as Bell 202 or V23 tones. Here the transport layer is more like Bellcore even though the data format looks much like British Telecom’s, because of this, European or North American kits are more likely to detect it. The basic principle of Frequency Shift Keying is at least a century old. Despite its age, FSK has successfully maintained its use during more modern times and has adapted well to the digital domain, and continues to serve those that need to transfer data via computer, cable, or wire. There is no doubt that FSK will be around as long as there is a need to transmit information in a highly effective and affordable manner.

A. Modulator and detector principles of operation

PSK and ASK, and sometimes also FSK, are often generated and detected using the principle of QAM. The I and Q signals can be combined into a complex-valued signal $I+jQ$ (where j is the imaginary unit). The resulting so called equivalent lowpass signal or equivalent baseband signal is a complex-valued representation of the real-valued modulated physical signal (the so called passband signal or RF signal).

These are the general steps used by the modulator to transmit data:

1. Group the incoming data bits into codewords, one for each symbol that will be transmitted.
2. Map the codewords to attributes, for example amplitudes of the I and Q signals (the equivalent low pass signal), or frequency or phase values.
3. Adapt pulse shaping or some other filtering to limit the bandwidth and form the spectrum of the equivalent low pass signal, typically using digital signal processing.
4. Perform digital-to-analog conversion (DAC) of the I and Q signals (since today all of the above is normally achieved using digital signal processing, DSP).

5. Generate a high-frequency sine wave carrier waveform, and perhaps also a cosine quadrature component. Carry out the modulation, for example by multiplying the sine and cosine wave form with the I and Q signals, resulting in that the equivalent low pass signal is frequency shifted into a modulated passband signal or RF signal. Sometimes this is achieved using DSP technology, for example direct digital synthesis using a waveform table, instead of analog signal processing. In that case the above DAC step should be done after this step.

6. Amplification and analog bandpass filtering to avoid harmonic distortion and periodic spectrum

At the receiver side, the demodulator typically performs:

1. Bandpass filtering.
2. Automatic gain control, AGC (to compensate for attenuation, for example fading).
3. Frequency shifting of the RF signal to the equivalent baseband I and Q signals, or to an intermediate frequency (IF) signal, by multiplying the RF signal with a local oscillator sinewave and cosine wave frequency (see the superheterodyne receiver principle).
4. Sampling and analog-to-digital conversion (ADC) (Sometimes before or instead of the above point, for example by means of undersampling).
5. Equalization filtering, for example a matched filter, compensation for multipath propagation, time spreading, phase distortion and frequency selective fading, to avoid intersymbol interference and symbol distortion.
6. Detection of the amplitudes of the I and Q signals, or the frequency or phase of the IF signal.
7. Quantization of the amplitudes, frequencies or phases to the nearest allowed symbol values.
8. Mapping of the quantized amplitudes, frequencies or phases to codewords (bit groups).
9. Parallel-to-serial conversion of the codewords into a bit stream.
10. Pass the resultant bit stream on for further processing such as removal of any error-correcting codes.

As is common to all digital communication systems, the design of both the modulator and demodulator must be done simultaneously. Digital modulation schemes are possible because the transmitter-receiver pair have prior knowledge of how data is encoded and represented in the communications system. In all digital communication systems, both the modulator at the transmitter and the demodulator at the receiver are structured so that they perform inverse operations. Non-coherent modulation methods do not require a receiver reference clock signal that is phase synchronized with the sender carrier wave. In this case, modulation symbols (rather than bits, characters, or data packets) are asynchronously transferred. The opposite is coherent modulation.

IV. OPERATIONAL ANALYSIS

The usage of the power grid for control, maintenance, and charging purposes by the utility commodities has a long history. The liberalization of telecommunications and the deregulation of electricity utilities have added new dimensions to the potential application of the electricity infrastructure for the most efficient use of the local loop. Furthermore, the birth and growth of the Internet accelerate the demand for digital telecommunications services to almost every premise. If such services can be carried over electricity distribution networks, a truly universal information superhighway might be realized, with the capability of providing interconnection to every home, factory, office, and organization. Electrical distribution circuits constitute a universal wiring system, hut they were not built for communication purposes. Varying levels of impedance and attenuation due to switching of electrical equipment are frequent. Time-variant interference from various sources leads to a very poor performance of the system. **As** a result the transmission capabilities restricted resulting to severe bandwidth constraints, power limits, and high levels of noise. In **1838** the first remote electricity supply metering and in **1897** [3] the first patent on power line signaling were proposed in the United Kingdom. In **1905** applications were patented in the United States, and in 1913 the first commercial production of electromechanical meter repeaters took place. By late **1980,** relatively sophisticated error control coding techniques within the hardware of PLC modems were proposed. PLC standards have evolved constantly over the years, especially the last 20, and resulted after **1994** in the digital power line boost promising new revenues for energy utilities and cheap Internet access for consumers.

Medium voltage lines used as backbones for telecom operators have become a mature technology. Clearly the main focus is and will continue to be on the connection between house and transformer as a solution for the “last dirty mile” problem. Furthermore, new interest arises due to recent developments regarding in-house networking. However, to develop these applications in a commercially attractive way seems to still be hard for various reasons. Essentially, what is missing is a clear regulatory framework. In Europe the CENELEC hand **(3-148.5** kHz) is currently allocated to classic narrowband applications, with a maximum signal power of **5** mW and rates up to 144 khz over distances around 500 m. However, today these applications seem very conservative, and research has focused on transmission Frequencies via power lines above **1** MHz. Power line telecommunications (PLT) systems arc demanded for data rates of several megabits per second. These systems operate over low voltage electricity distribution networks (LVEDNs) and are capable of providing commercially attractive broadband digital access solutions. The need to harmonize broadband wire line access technologies with existing radio services so that coexistence might be optimized will be a key element in the rapid deployment of broadband PLT systems. The subject of EMC and broadband power line communications (PLC) applications, which propose to utilize sections of the high frequency bands, are now the focus of much detailed research (www.plcforum.org). The main issues encountered in such research are treated in brief in the following paragraphs. Academic and industrial activities are covered thoroughly, illustrating the open topics for discussion and further interpretation. Then channel modeling and measurement techniques are given, followed by communication techniques. The hot topic of regulation is covered, and finally, market status and perspectives are investigated.

A. *Channel Characteristics*

Power lines constitute a rather hostile medium for data transmission. Varying impedance, considerable noise, and high attenuation are the main issues. The channel mixes the nasty behavior of a power line with that of a communication channel. The transmission environment for PLC seems much worse than that for mobile communications, so we need to not only utilize existing advanced technologies, but also create novel ones. Channel characteristics can be both time- and frequency-dependent, and also dependent on the location of transmitter and receiver in the specific power line infrastructure. Hence, the channel can in general be described as random time varying with a frequency-dependent signal-to noise ratio **(SNR)** Over the communication bandwidth. Gellerdlly, a measured in-house (10 m) transfer function shows some deep narrowband notches spread over the whole frequency range. Phase angles decrease with frequency, and at amplitude notches we note phase nonlinearities. Quite a few measurements in the frequency and time domains for high-hit-rate transmission have been reported, converging essentially to some general conclusions (Fig. 2).

Impedance is highly varying with frequency and ranges between a few ohms and a few kilo ohms with peaks at some frequencies where the network behaves like a parallel resonant circuit. In most frequency ranges the impedance shows inductive or capacitive behavior around 90 **R** tu 100 *Cl.* The net impedance is strongly influenced by the network topology and connected loads, so we can say that the low voltage mains do not have essentially characteristic impedance since loads being switched vn and oIf randomly introduce **a** change in impedance. Characteristic indoor and outdoor records of ***attenuation*** have been reported in the literature. Measurements have been made at a voltage of *0.35* V RMS on in-house line;, resulting in about 15 dB attenuation, and on a 1 km cable feeding a cluster of houses, resulting in 50 dB attenuation. In the range of frequency of 9-95 kHz the line losses ranged between 40-100 dB/km depending on the location where the attenuation was measured. *So* far research has focused on LVEDNs, but some studies **on** medium voltage cables (10-30 **kV)** were reported**.** A large variety of cables exist differing in general structure, number of cores, conductor material, and insulation used.

B. *Noise*

Communication signals at low frequency are propagated along the low voltage power line through conducted emission with very little energy radiated from the line causing interference to other communication services. Different noise sources, motors, radio signals, and power supplies result in a noise CUIVI: very much dependent on location and time. Generally, channel noise varies strongly with frequency, load, time of day, and geographical location. The noise spectrum in the frequency range up to **145** kHz consists of four types of noise.

Colored background noise, which is the summation of low power-sources like universal motors. Its power spectral density is frequency-dependent and decreases for - increasing frequencies. Periodic impulse noise (synchronous and asynchronous to the power frequency) stemming from appliances that produce harmonics of *50* or 100 Hz. Narrowband noise consisting of sinusoidal signals with modulated amplitudes (radio stations, the horizontal retrace frequency for television, etc.). Asynchronous impulsive UOiSC (noise bursts of switching operations), attenuation as well as impulse and background noise measurements are reported. The noise power level ranges according to the distance between the noise source and receiver, and in most cases was found to be below 40dB. Significant noise sources are universal motors to frequencies up to 50 kHz. It is worth mentioning that, since noise as well as wanted signals is subject to attenuation, noise sources close to the receiver will have the greatest effect on the received noise structure, particularly when the network attenuation is large.

C. *Modeling and Simulation Tools*

For efficient communications a thorough understanding of the power line channel described with as few parameters as possible is required. The modeling approach is generally based on the transfer function and additive noise studies. The received signal is often modeled as the sum of a filtered version of the transmitted and interfering signals. These characteristics are dependent on frequency, time, and location of the transmitter and receiver in a specific power line infrastructure. Measurements show that channel characteristics do not change very quickly, and coherence time is large compared to typical symbol duration; hence, the channel model is quasi stationary. There are several approaches to modeling the transfer characteristics of power lines that we can classify in two categories:

- The ***hardware*** approach, based on impedance of the cables and network tool.
- The ***communication*** approach, where the channel is modeled **by** its attenuation, phase shift or noise sources, insertion losses, and so on.

This model permits us to use classical communication methodologies and tools to estimate expected performance**.** Some modeling tools have been developed based on transmission line theory using a mathematical approach, while others are based on physical measurements of the nodes.

D. *Channel Model*

The communication channel is assumed to be flat fading, quasi-static. The path gains, from one emitting point to one receiving point of the same phase (wire), are modeled as samples of complex Gaussian random variables with variance 0.5 per real dimension. In the simulation’s transmission model we assume that each phase provides a completely isolated path to the transmitted signal.

Opposite to many other communication channels, the power line channel does not represent an Additive White Gaussian Noise (AWGN) environment. In the frequency range from some hundred kHz up to 20 MHz it is mostly dominated by narrow-band interference and impulsive noise. One suitable model for this type of noise is the Additive White Class A Noise (AWCN).AWCN is calculated from the combination of AWGN and impulsive noise. The PDF of a Class A noise real variable x is given by:

$$p(x)=\frac{1}{\sqrt{2\pi}}\sum_{n=1}^{\infty}\frac{1}{\sigma_m}a_m\exp\left(-\frac{x^2}{2\sigma_m^2}\right) \qquad (1)$$

where

$$a_m=e^{-A}\frac{A^m}{m!},\quad \sigma_m^2=\sigma^2\frac{(m/A)+T}{1+T},\quad \sigma^2$$

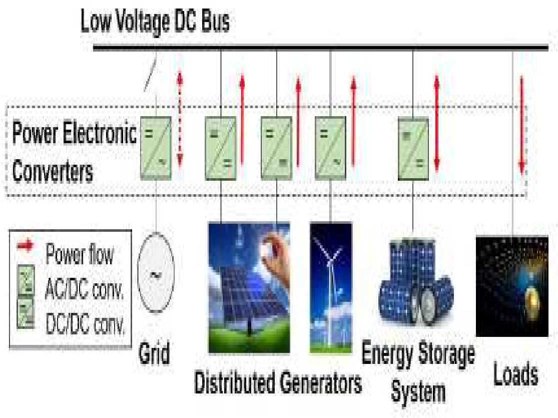
: is the variance of Class A noise, $T=\frac{\sigma_g^2}{\sigma_i^2}$, σ_g^2 is the variance of the AWGN component and σ_i^2 the variance of the impulsive component. The parameter A is called the impulsive index. For small A, for example A=0.1, the noise is highly impulsive whereas for A→ ∞ the Class A noise pdf becomes Gaussian. A Class A noise sample can be expressed as:

$$n=x_G+\sqrt{K_m}\,y \qquad (2)$$

where: x_G is white Gaussian background noise sequence with zero mean and variance σ_g^2, K_m is statistically independent, Poisson distributed random sequence whose pdf is characterized by A (mean value of Poisson distribution), and y is white Gaussian sequence with zero mean and variance σ_i^2/A.

E. System Structure

The general layout of the simulated system can be seen below in figure. The data to be transmitted is first coded with Convolutional coding (2,1); the generator polynomial used is [133,171]. The reason why we use Convolutional coding is that it is widely used in wireless channels with very good performance results. Convolutional coding is designed for correcting random errors. In fading channels with high levels of impulsive noise, however, like PLC, the errors have a burst nature. This can be controlled using Burst Error Correcting Techniques. One of them is the Block Interleaving. The signal is block interleaved with interleaving depth 40.The modulation schemes under test are 4-PAM and BPSK. The former modulation type used to be the most common in PLCs some years ago, and it is still applied sometimes when simulating a PLC system. On the other hand, the latter modulation scheme is the most popular in applications using wireless and power line channels today. The STBC scheme has three emitting points and three receiving points, because of the three phases of the PLC channel. The transmission matrix used to produce the encoder and the decoder was described above in (4).Finally, we should mention that perfect channel estimation is assumed at the receiver.

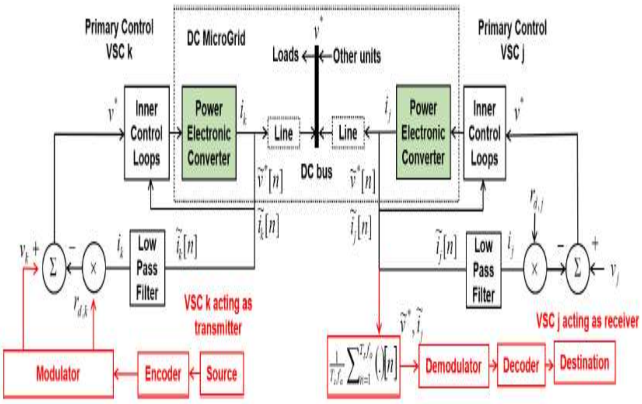


Existing systems have communication between DC bus, where it is an integral part of a macro or micro power grid. Ac power is invariably derived from non-renewable energy sources such as thermal power plant. Micro grids are realized using wind mills, solar panels and fuel cells. There exists huge load current variations in the cable meant for our communication. Hence, data loss and its associated minimization has not been concentrated in existing work. The transmitter end consists of a digital data source followed by encoder and modulator. Similarly, the receiver consists of decoder and demodulator. It is seen that no channel encoders are employed in earlier works. BER of existing channel completely depends on the amount of load current and hence any low pass filtering will lead to loss of data. In existing system, the power can flow from any direction to any direction, where bidirectional converters are employed.

F. Encoding and Decoding

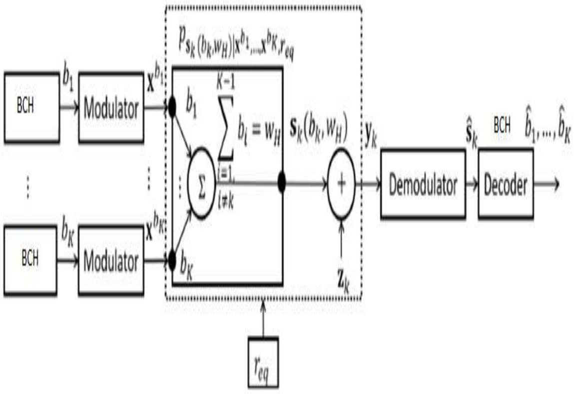
The *encoding* of a message is the production of the message. It is a system of coded meanings, and in order to create that, the sender needs to understand how the world is comprehensible to the members of the audience. In the process of encoding, the sender (i.e. encoder) uses verbal (e.g. words, signs, images, video) and non-verbal (e.g. body language, hand gestures, face expressions) symbols for which he or she believes the receiver (that is, the decoder) will understand. The symbols can be words and numbers, images, face expressions, signals and/or actions. It is very important how a message will be encoded; it partially depends on the purpose of the message. The *decoding* of a message is how an audience member is able to understand, and interpret the message. It is a process of interpretation and translation of coded information into a comprehensible form. The audience is trying to reconstruct the idea by giving meanings to symbols and by interpreting the message as a whole. Effective communication is accomplished only when the message is received and understood in the intended way. However, it is still possible for the message recipient to understand a message in a completely different way from what was the encoder was trying to convey. This is when "distortions" or "misunderstanding" arise from "lack of equivalence" between the two sides in communicative exchange.

V. EXTENDED ANALYSIS



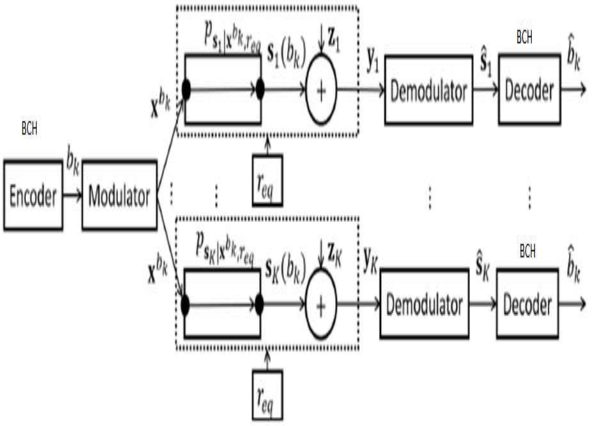
In this project, we develop power talk communication strategies for Direct-Current (DC) MG systems with arbitrary number of control units that carry out all-to-all communication. We investigate the effects that some exemplary solutions for coping with the sporadic load changes by resetting the detection spaces have on power talk rates. Finally, we investigate what is the cost of power talk in terms of power consumption. We design power talk solutions for scenarios with multiple, all-to-all communicating units. The corresponding multiple access channel is realized in the bus voltage level controlled jointly by all units in the system. We apply the concept of signaling space, where the symbol constellations are designed such that the MG operation constraints are not violated.

A. *Transmitter and Receiver (Mode 1)*



The data from the BCH coder is arranged serially with appended zero, in order to maintain the frame length. This coded data b1, b2….bn are modulated using, phase shift keying . The data sources from multiple data channels are multiplexed. X^{b1}, X^{b2}, X^{bk} are now added with a noiseZk is assumed to be added in data due to communication.

B. *Transmitter and Receiver (Mode 2)*



The MODE1 and MODE 2 differs just in the way that data is multiplexed at encoder stage or modulation stage. In mode 2, the data is multiplexed at encoder stage itself. The data from the BCH coder is arranged serially with appended zero, in order to maintain the frame length. This coded data b1, b2….bn are modulated using, phase shift keying. The data sources from multiple data channels are multiplexed. X^{b1}, X^{b2}, X^{bk} are now added with a noise Zk is assumed to be added in data due to communication.

C. *BCH Codes*

In coding theory, the **BCH codes** form a class of cyclicerror-correcting codes that are constructed using finite fields. BCH codes were invented in 1959 by French mathematician Alexis Hocquenghem, and independently in 1960 by Raj Bose and D. K. Ray-Chaudhuri. The acronym *BCH* comprises the initials of these inventors' surnames (mistakingly, in the case of Ray-Chaudhuri). One of the key features of BCH codes is that during code design, there is a precise control over the number of symbol errors correctable by the code. In particular, it is possible to design binary BCH codes that can correct multiple bit errors. Another advantage of BCH codes is the ease with which they can be decoded, namely, via an algebraic method known as syndrome decoding. This simplifies the design of the decoder for these codes, using small low-power electronic hardware.BCH codes are used in applications such as satellite communications, compact disc players, DVDs, disk drives, solid-state drives and two-dimensional bar codes.

i. *Primitive narrow-sense BCH codes*

Given a prime powerq and positive integers m and d with $d \leq q^m - 1$, a primitive narrow-sense BCH code over the finite field GF(q) with code length $n = q^m - 1$ and distance at least d is constructed by the following method. Let α be a primitive element of $GF(q^m)$. For any positive integer i, let $m_i(x)$ be the minimal polynomial of α^i over GF(q). The generator polynomial of the BCH code is defined as the least common multiple$g(x) = \mathrm{lcm}(m_1(x),\ldots,m_{d-1}(x))$. It can be seen that g(x) is a polynomial with coefficients in GF(q) and divides $x^n - 1$. Therefore, the polynomial code defined by g(x) is a cyclic code.

The data to be transmitted is first source encoded and then it is applied to a bandwidth efficient encryption method. The key generated is equal to the number of data bits to be transmitted. The data is primarily exored with the key. The key is assumed to be known only to the receiver. Further the data is applied to BCH encoder in order to protect the data bits from noise. Then the data is further applied to the modulator where a PSK is employed. At the receiver end , exactly reverse process is carried in order to extract the transmitted bits. The communication part is implemented with script based programming and power system has been designed with Simulink block sets. A system with a AC generator with bidirectional converter has been taken as a power line communication platform. The data generated from the transmitter end after modulation is injected into the power system DC bus, and after it travels over several kilomters of distance and after a line impedance, the data is received using a simout block. This data is then exported to workspace where the demodulation and decoding process takes place. The modulated communication signals are in the range of -1 to 1 voltage and the DC bus voltage is in the order of 130V. At the receiver, this DC bias is filtered using a high pass filter designed with RC filter whose cut off frequency is given by fc= 1/ (2*pi*RC).

VI. SIMULATION RESULTS

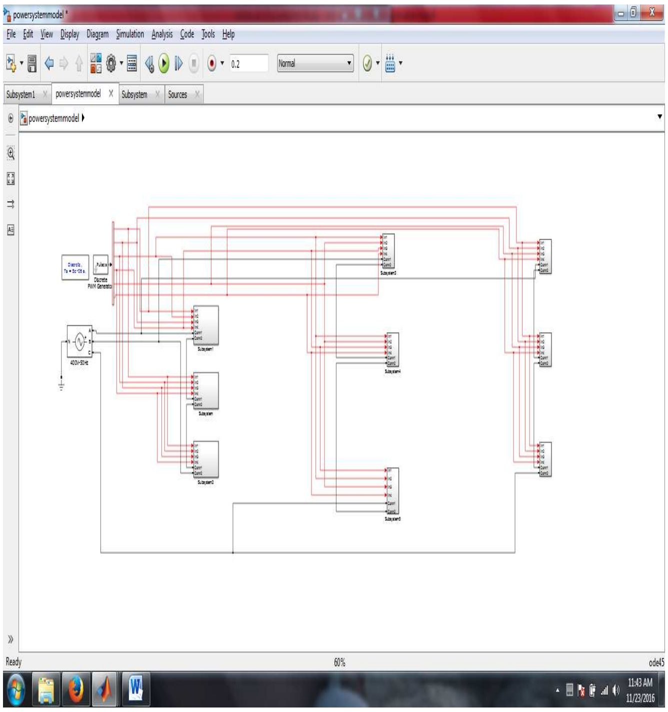


Fig.5.1 Overall model

The Simulink model shown in the figure _, gives a functioning of power distribution system, where the AC power generated is rectified into DC. Further the DC is up converted or down converted based on the requirement using DC boost or buck converters. The diagram shows that, the system is capable of producing such 9 dc sources. In order to show the communication in between the DC channel, an example system is simulated using matlab version 2013 using power system and power electronics block sets.

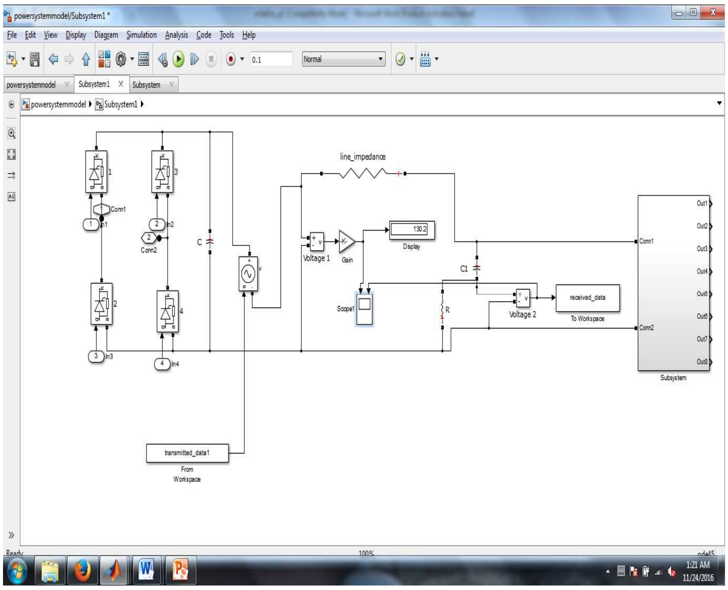


Fig.5.2. Transmission and Reception

The Simulink model presented above is a sub system of previous Simulink model. This consists of a controlled rectifier and a DC bus ending up with another bidirectional DC to DC converter. Now our aim is transmit a data at the start of DC bus and receive the same at the end of DC bus. This is assumed to be communication channel in our experiment. The data is generated using matlab script and run separately and then the same is applied to this Simulink model by invoking the variables in matlab workspace. The data crosses all the way in noisy DC bus, and reaches the other part of the DC bus. The DC bus impedance can be adjusted in simulation as the Bit Error Rate required.

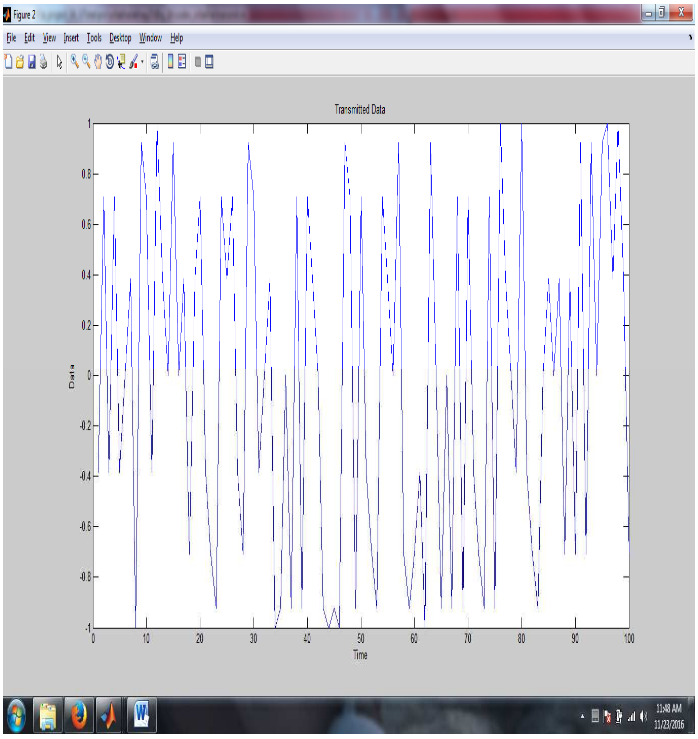


Fig.5.3 Transmitted Data

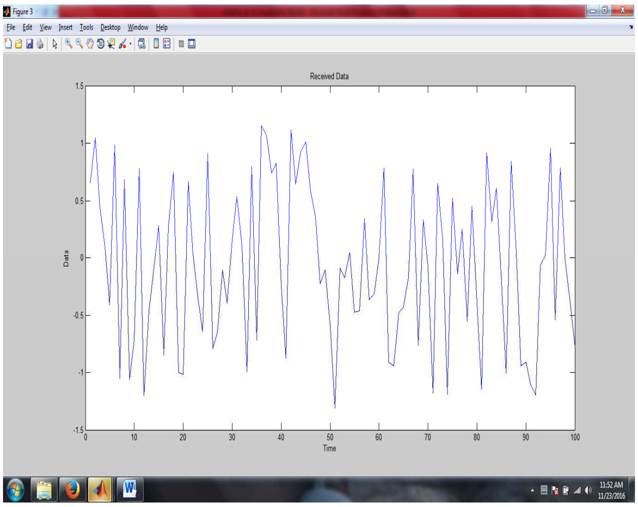


Fig.5.4 Received Data Under 10 Db Of Snr

The waveforms shown above are transmitted modulated signal at 10 DB of Signal to noise ratio. It may be seen that there exists huge changes in the received waveforms because of less SNR. Y axis is the real part of the modulated is signal, whereas X axis shows the time in seconds.

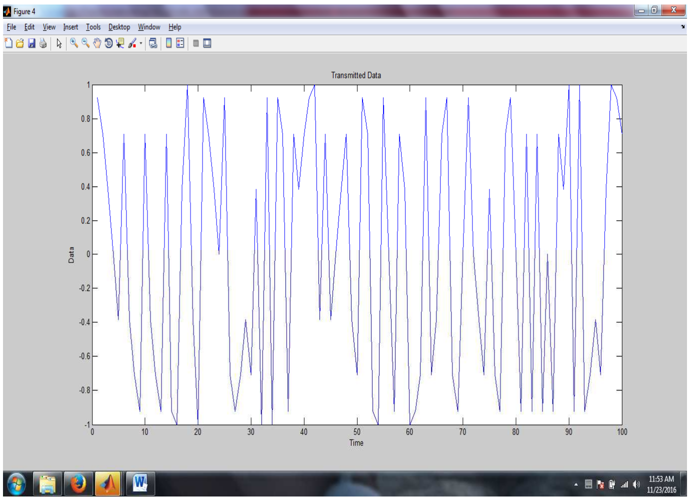


Fig.5.5 Transmitted and Received data at 20 db

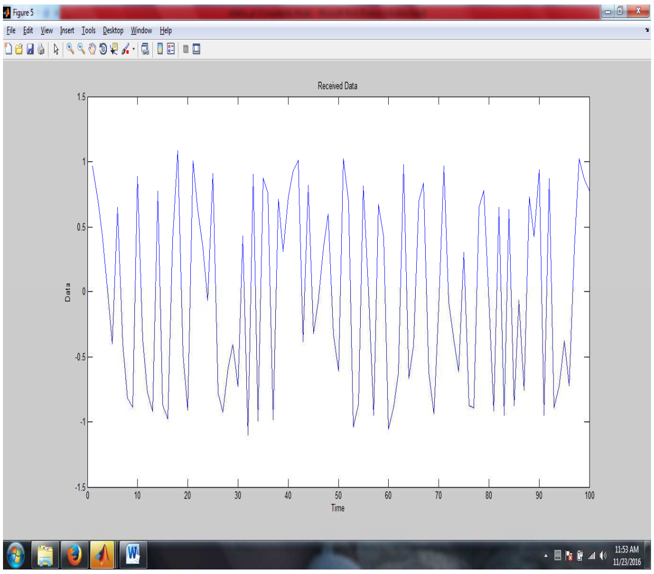


Fig.5.6 Received Data Under 20 Db Of Snr

The waveforms shown above are transmitted modulated signal at 20 DB of Signal to noise ratio. It may be seen that the received waveform is almost same as transmitted waveform because of 10 dB increase in SNR. Y axis is the real part of the modulated is signal, whereas X axis shows the time in seconds.

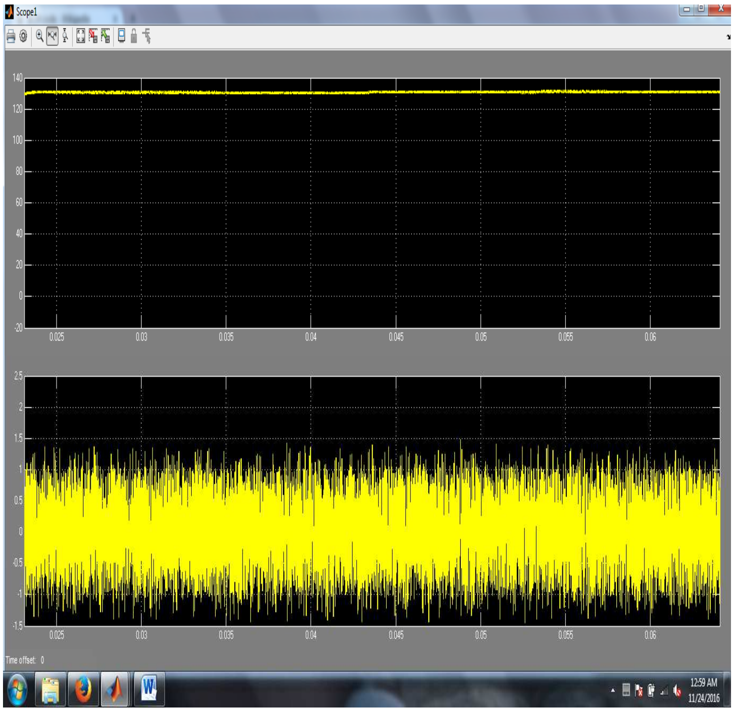


Fig.5.7 Outputs Seen In Power Grid (Dc Bus Side)

The waveforms shows the DC voltage and its corresponding data separated with 20000 samples. The DC bus voltage is around 130 V, which consists of communication data in the modulated form. The second waveform shows only the modulated communication signal, (real part of the signal)

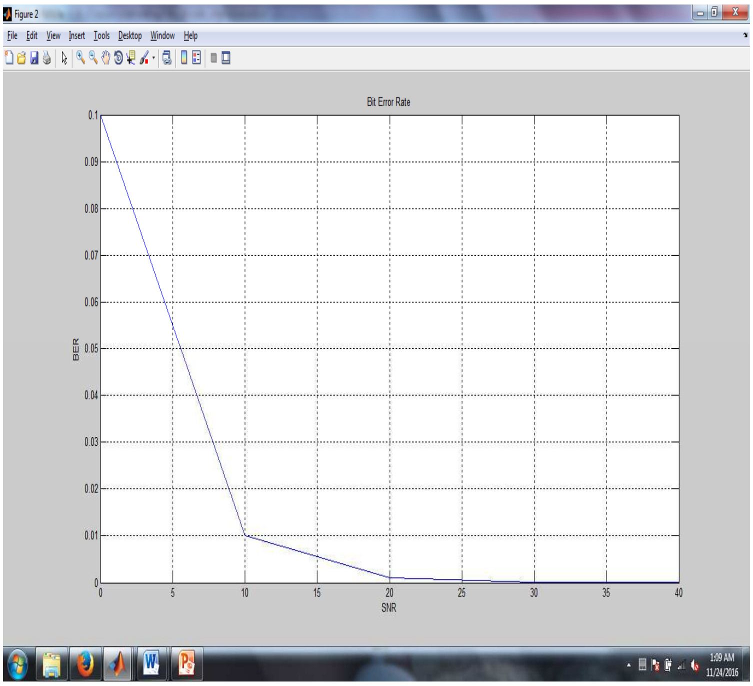


Fig.5.8BER Performance

X –axis – SNR in dB
Y axis – BER (No unit)

The above figure shows clearly that, the communication system performs well when operated wdith higher SNR. Since power channel occupied by noise fully, it is worse than the air media or common power free bus. We could achieve a least BER at 25 dB as seen in the figure.

VII. CONCLUSION & FUTURE WORK

In this project we presented power talk, a novel concept for communication among units in a Micro Grid. The core idea of power talk is to modulate information using primary control loops of the voltage source converters that regulate the bus voltage. A total of 400 samples have been taken and transmitted over a power channel under DC bus load conditions. The performance has been evaluated for various values of SNR ranging from 0 to 40 db. We have shown that it is possible to design power talk signaling constellations that conform to the operating constraints and power deviations limits. We have also shown that using MAP detector at the receiving end has an exception performance when the load (i.e., power demand) is stable, under mild constraints on the number of units in the system and allowable power deviations. The main challenge of power talk are random load variations, leading to the uncontrollable changes of the bus voltage. We investigated techniques to counter effect load changes, showing that it is possible to optimize the power talk operation given the statistics of the load changes. Hardware implementation has been done with a set of micro controller interfaced with RS 232 standards. A PC based manual control of loads and an automatic control via wireless feedback is also done. However, the communication in forward direction is realized using DC bus available in the PV based micro grids.

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